

NOISE REDUCTION EFFORTS FOR THE INFRARED BEAMLINE AT THE ADVANCED LIGHT SOURCE

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Abstract

The quality of infrared microscopy and spectroscopy data collected at synchrotron based sources is strongly dependent on noise. We have successfully identified and suppressed several noise sources affecting Beamline 1.4.3 at the Advanced Light Source (ALS), resulting in significant reductions to the noise in the users' FTIR spectra. In this paper, we present our methods of noise source analysis and the techniques used to reduce the noise and its negative effect on the infrared beam quality. These include analyzing and changing physical mounts to better isolate portions of the beamline optics from low-frequency environmental noise, and modifying the input signals to the main ALS RF system. We also discuss the relationship between electron beam energy oscillations at a point of dispersion and infrared beamline noise.

INTRODUCTION

Noise reduction for this beamline has been an ongoing project since it was commissioned in 1997. Transverse motions of the photon beam are transformed into intensity variations in the IR signal by an aperture or apertures in the beamline optics. There are two main sources of this photon beam motion: mechanical vibrations of beamline components and electron beam motion introduced by energy oscillations at a point of dispersion in the ring (the bending magnet IR source). The first noise type was previously lowered by mechanically isolating beamline components from environmental vibrations and the remaining noise damped with an active mirror feedback system [1-4]. Higher-frequency noise caused by electron beam motion was dramatically diminished when a quieter master oscillator was installed in the ALS RF system [5]. In order to further reduce noise in the FTIR spectra and bring the signal-to-noise levels closer to what is achieved using a standard Glowbar IR source, we revisited both of these noise types to further improve them.

DETAILS

Fourier transformed time domain signals from the first optical detector in the mirror feedback system and from the FTIR detector signal gave us baseline noise measurements. The spontaneous noise from 0-200Hz and 0-25kHz is shown in Fig. 1.

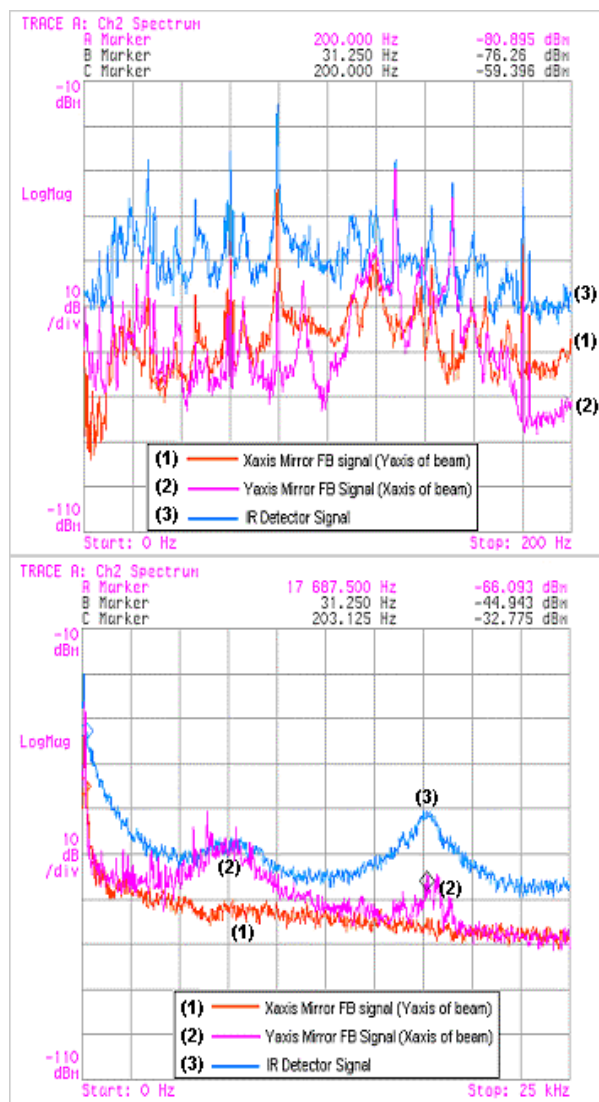


Figure 1. Spontaneous noise spectra at the Infrared Beamline 1.4.3, prior to any of the improvements discussed in this report.

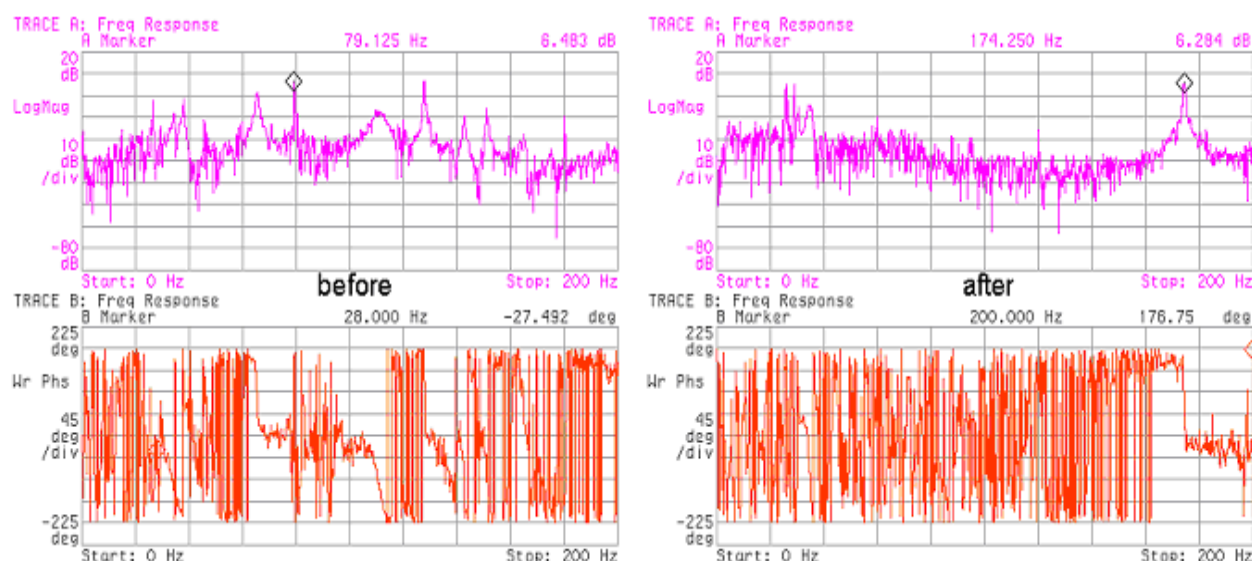


Figure 2. Transfer functions of the IR signal before and after the M2 mechanical modification. A distinct slope in the lower phase plot indicates a vibration correlated to the driving frequency and therefore a significant mechanical oscillation. Many of the mechanical vibration modes were reduced, especially those at 65 Hz, 110 Hz, 128 Hz. The peak that arose at 175 Hz is still under investigation.

Low frequency noise

In the low frequency range (0-200 Hz), previous mechanical isolation efforts identified the M1 and M2 beamline mirrors⁶ as the main suspects for vibration induced noise. To further characterize this noise, a Wilcoxon Research Model F3 Electromagnetic Shaker was clamped to the mirror housing and transfer functions were taken by sweeping the driving frequency from 0 Hz to 200 Hz and recording the response of the signal from the first optical detector of the mirror feedback system and from the FTIR bench.

Upon seeing numerous correlated vibration peaks indicative of mechanical motion, it was discovered that a tensioning spring had been left out of the M2 mirror assembly.

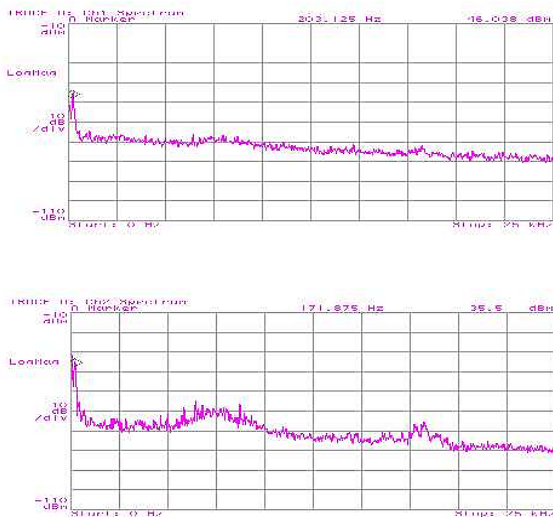
The spring was installed and adding motor drive shafts for external adjustment further confined mirror motion. Transfer function measurements following these modifications showed a marked improvement in mirror stability and dropped noise levels in the lower frequencies of the FTIR signal, as seen in Fig. 2.

High frequency noise

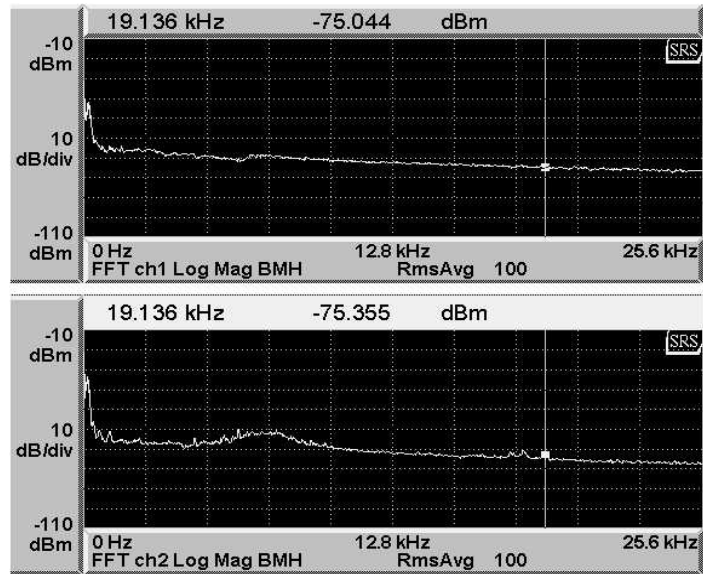
At higher frequencies (500 Hz – 25kHz), mechanical vibrations are unlikely to be the cause of noise, so any introduced noise is most likely coming from transverse motion of the electron beam.

Fig. 1 shows that there are noticeable noise peaks centered at about 7.5 kHz and 18 kHz in the y-axis of the optical detector and in the overall IR signal, but none in the x-axis of the optical detector signal.

Due to the configuration of the beamline, x-axis beam motion is observed on the y-axis of the detector, and vice-versa, and so the traces correspond to what one would expect for horizontal beam oscillations. We know that the 7.5 kHz peak is due to synchrotron oscillations of the beam, because it slowly shifts as the beam current decays and also changes with beam energy. There is little that can be done to damp this oscillation. The 18 kHz peak, on the other hand, was also observed on the x-axis signal of a storage ring beam position monitor. This noise was found to be coming from a DAC output in the storage ring RF phase shifter system. The output of the DAC was filtered by the RF group and Fig. 3 (on the next page) shows the result – the 18 kHz noise is mostly gone.



before



after

Figure 3. 0-25 kHz spontaneous noise on the first mirror feedback optical detector before and after RF phase shifter DAC filtering. The upper and lower plots represent vertical and horizontal electron beam motion, respectively. Different scopes were used, but the ranges are the same. Notice the substantial reduction in the 18 kHz peak in the bottom-right plot. The broad 7.5 KHz peak is due to synchrotron oscillations and is difficult to suppress.

CONCLUSION

Work on noise reduction efforts at BL 1.4.3 is ongoing. We are more thoroughly examining the beamline optics between the M2 mirror and sample stage to identify any particular aperture(s) where the photon beam motion is transformed to an amplitude modulation of the IR signal. The incoming infrared light also contains harmonics of 60 Hz power line noise, a problem noted by infrared beamlines at other synchrotron facilities. It is suspected that this noise is introduced by the RF system, but attempts at filtering it have been unsuccessful so far. With further noise improvements, we hope to bring the signal-to-noise ratio to a level competitive with other IR sources and increase the demand for synchrotron-based infrared science.

REFERENCES

1. J.M. Byrd, M.C. Martin, and W.R. McKinney, in 1999 Particle Accelerator Conference, eds. A. Luccio and W. MacKay, (New York, 1999), p. 495.
2. J.M. Byrd, in 1999 Particle Accelerator Conference, eds. A. Luccio and W. MacKay, (New York, 1999), p. 1806.
3. J.M. Byrd, M.Chin, M.C. Martin, W.R. McKinney, and R. Miller, SPIE Proceedings, 1999, Vol. 3775, pp.58-64. LBNL-44134
4. W.R. McKinney, M.C. Martin, J.M. Byrd, R. Miller, et al., SPIE Proceedings, 1999, Vol. 3775, p. 37.
5. J.M. Byrd, Proceedings of the 1999 Particle Accelerator Conference, New York, Editors: A. Luccio, W. MacKay, p. 1806, 1999. LBNL-43031
6. A schematic of Beamline 1.4 is available at http://www.als.lbl.gov/als/als_users_bl/1.4.3-Datassheet.pdf.

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